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by B.H. Moody

NEWFOUNDLAND FOREST RESEARCH CENTRE
ST. JOHN'S, NEWFOUNDLAND
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ABSTRACT

The productive balsam fir - spruce forest of Newfoundland and Labrador was surveyed in August 1977 and 1978 to detect and assess the damage caused by the present spruce budworm [Choristoneura fumiferana (Clem.)] outbreak. A general aerial mapping, augmented by ground sampling, was used in the survey. In Newfoundland, tree mortality in 1978 occurred in 300 400 hectares of merchantable balsam fir stands containing a total timber volume of 22 398 521 m^3. These stands contained an estimated 6 547 000 m^3 of timber as dead trees and 4 841 000 m^3 as dying trees. In Labrador, the volume of dead and dying trees scattered within the severely damaged areas (31 796 hectares) was about 770 000 m^3. The accuracy of the damage assessment method is estimated and discussed.

Les forêts productives de sapin-baumier de Terre-Neuve et du Labrador ont été inspectées an août 1977 et 1978 pour détecter et évaluer les dégâts causés par l'invasion actuelle de la tordeuse des bourgeons de l'épinette [Choristoneura fumiferana (Clem.)]. On a utilisé pour cette inspection une carter aérienne générale ainsi que des échantillons pris au sol. A Terre-Neuve, les arbres atteints de facon mortelle représentaient 300 400 hectares de sapins-baumiers vendables sur pied et un volume total de bois de construction de 22 398 521 m^3. Ces arbres sur pied contenaient environ 6 547 000 m^3 de bois de construction lorsque déjà morts et 4 841 000 m^3 pour ceux qui étaient en train de mourir. Au Labrador, le volume d'arbres morts ou mourants éparpillés ca et là dans des endroits très affectés (31 796 hectares) était environ 770 000 m^3. L'exactitude des méthodes d'évaluation des dégâts est appréciée et discutée.

ACKNOWLEDGEMENTS

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SPRUCE BUDWORM DAMAGE ASSESSMENT IN NEWFOUNDLAND IN 1977 AND 1978

by

B.H. Moody

INTRODUCTION

The present outbreak of the spruce budworm started in 1971 and expanded from a few hectares in western Newfoundland to virtually all of the balsam fir-spruce stands of the Island by 1977 (Otvos and Moody 1978). Estimates of the areas of spruce budworm defoliated forests have been computed annually from aerial surveys since 1971. The figures ranged from a low of 20 hectares (50 acres) in 1971 to 647 250 hectares (1,599,370 acres) in 1972 to 2 730 520 hectares (6,747,280 acres)[1] in 1977. In 1977, a special aerial damage assessment survey in August, augmented with ground checks, was conducted to determine the area(s) and merchantable volume of dead and damaged stands. This survey was improved in 1978 and covered virtually all of the infested forests.

This paper describes the methodology and results of the 1977-1978 Province-wide spruce budworm damage assessment.

METHODS

The Forest Resources Surveyed

The productive forests of insular Newfoundland (Appendix I) covers about 3.8 million hectares (9.4 million acres) (Anon. 1974). There are just under 281.7 million m^3 of merchantable wood in the Island's forests.[2] Three-quarters of this total volume is in softwood stands, just under 20% in mixedwood stands and 5% in hardwood stands. Most of the volume consists of three species: balsam fir, Abies balsamea (L.) Mill. (49% of the total), black spruce, Picea mariana (Mill.) (34% of the total) and white birch, Betula papyrifera Marsh. (11% of the total). The productive forest of Labrador covers about 5.3 million hectares (13 million acres) and consists of black spruce and balsam fir. Only about half of the total is sufficiently productive and accessible to be of any commercial value. The volumes of merchantable wood in the commercial forest areas of Labrador are estimated at about 93.4 million m^3, and about 70% is black spruce (Anon. 1974).

Aerial Survey

The Forest Insect and Disease Survey (FIDS) conducted detailed low altitude aerial surveys of defoliation of forest stands and in 1977 initiated a damage assessment survey. The infested areas were again re-examined in August 1978 by the same personnel. A Beaver fixed-wing aircraft was used flying at about 430 m altitude at a speed of 130-160 km/h.

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[1] 1 hectare = 2.471 acres

[2] 1 m = 2.41 cords (1 cord = 85 cu ft.)

Two experienced observers, one seated on each side of the aircraft, together examined a 2.4 km wide strip of forest in a flight line. This arrangement was used to survey all the infested forest area.

A coding system was used to mark on the 1:250,000 scale topographic map sheets the following categories of spruce budworm damage:

Merchantable trees

Code		Category
a	-	Dead standing
b	-	Moribund, severely damaged and not likely to recover
c	-	Severely damaged but likely to recover
d	-	Lightly damaged

Submerchantable trees

Regen. a	-	Severely damaged with mortality
Regen. b	-	Moderate to severe damage, no mortality

Each observer recorded the forest conditions by marking the appropriate code as densely as possible on his map.

The criteria used in identifying the above damage categories from the air were:

Dead stands	-	Appearance of total greyness on trees; no visible green foliage, and ground often visible (Blowdown trees from previous kill were noted).
Moribund stands	-	75% or more total defoliation, dead tops may or may not be present, long grey tops and occasional completely grey trees or small patches of grey.
Severely damaged stands	-	Considerable browning or reddish appearance of current growth over entire tree crowns; green foliage visible, occasional bare or dead tops.
Light damaged stands	-	Light browning of current shoots, some green current shoots evident, light to moderate previous damage.

Estimated percent of trees dead or moribund per area was denoted by placing the percentage beside the code mark (e.g. a 60%) (see Appendix II). Areas where tree blowdown occurred were denoted by the letter 'X' on the map. The assessment of the entire forests of the Island with a two-man crew required approximately 47 hours of flying time. An additional 15 hours were required in Labrador. The two sets of maps with codes of damage recorded were collated in the office by the two observers; areas of similar codes

depicting a damage category were delineated. The total area of productive forests were determined in each delineation using an electric planimeter and information from inventory maps concerning the distribution of productive forests.

Ground Check of Areas Selected from Aerial Survey Maps

Ground checks were conducted in selected merchantable forest stands classified from the air as dead, moribund and severely damaged. The intensity of ground sampling was restricted by the total number of sample points a two-man crew was estimated to be able to complete in a one-week period in 1977 and in two weeks in 1978. The estimated number of sample points were allocated to each area in proportion to its size. A helicopter transported the crew from one sampling location to another. Ground checks consisted of point-samples using a 10 factor prism, and where possible two points per location. In 1978 a total of 310 prism plots at 168 locations were sampled in 92 areas selected from a total of 135 areas delineated during the aerial survey (Appendix III).

The data recorded for each tree in the prism plot included species, diameter at breast height (dbh), tree height, dead or living tree, dead or living top, current defoliation (%), previous defoliation (%) and tree vigor (good, fair, poor, dying) (see Appendix IV). A tree was considered dead if the inner bark was brown when cut with a knife at two opposite locations at breast height and live if the inner bark was white. Dying trees included trees in vigor category "poor" and with more than 75% total tree defoliation.

In the winter of 1977-78, a special survey including 46 sample points in 23 of 92 "dead" stands were conducted to determine the proportion of dead balsam fir trees, the condition of dead trees (i.e. the number of years since death) and accessibility for salvage operations. The proportion of tree mortality was estimated by point sampling using a 10 factor prism. On dead trees, saprot penetration at breast height was measured and used to estimate the number of years since death (Hudak et al. 1978). In addition each stand was rated for accessibility using four classes as follows: 1 - accessibility by existing roads; 2 - road construction required; 3 - road construction required and major water bodies to be crossed; 4 - more than 50% of volume on slopes greater than 30%.

The areas not ground checked were small and the data recorded during aerial surveys were used to calculate volumes of dead and dying trees in these areas. Ground checks were also made in immature stands by recording damage in permanent sample plots.

Determination of Volumes in Damaged Stands

The third phase of the damage assessment survey consisted of determining the total amount of wood volume in each damage category for each area. This phase included the cooperation of all landholders, namely, the

Forestry Branch, Newfoundland Department of Forestry Resources and Lands, Bowater Newfoundland Limited and Price (Nfld.) Pulp & Paper Ltd. The areas classified and delineated on the topographic maps were divided by forest management unit (see Appendix V) and ownership and the area of each merchantable stand within a unit was measured. Each landholder was requested to supply volume figures for all merchantable forests in these areas. The areas delineated on the topographic maps were superimposed on inventory maps. The information was supplied in the following forms:

Price & Province - total volume and acres by stand type within each area

Bowater - average cords per acre (2.41 m^3 or 85 c. ft. per cord) for each area obtained from their inventory surveys

Average percent stems and percent volume of dead trees and dying trees per area were calculated from ground plot data. The percent volume figures obtained were then used to correct or adjust the figures on the aerial survey map. The total merchantable volume per area on Price (Nfld.) Pulp & Paper Ltd. and Crown Lands was used to calculate percentage volume of dead and dying trees per area. For stands on Bowater land, the computed gross acreages for each damaged area were reduced by 32%; a correction factor to eliminate sections of hardwood forest, nonforested lands, sub-merchantable stands, and water bodies too small to be mapped by aerial observers. The correction factor was calculated from 1969 forest inventory maps (Anon. 1974).

Summary of the Aerial and Ground Survey Data

All infested merchantable stands were further classified into damage categories based on average percent volume of dead and dying trees in the stands. The class limits of the damage categories were arbitrarily set as follows:

A - Dead: 50% or more of total volume of the stand dead.

B - Moribund, unlikely to recover: 20 to 49% of total volume dead or more than 50% of total volume dying (dying = 75% or more total defoliation).

C - Very severely damaged, likely to recover; 5 to 19% of total volume dead or less than 50% of total volume dying.

D - Severely damaged, likely to recover: severe damage but less than 5% of total volume dead or dying.

The above damage categories were used to summarize and report the results of the damage assessment survey.

RESULTS

Damage Accumulated to 1978

Tree mortality increased in those areas delineated in 1977 as containing dead and moribund balsam fir. Also there has been an increase in the total area in which tree mortality was occurring. The total net area of merchantable forest stands, in insular Newfoundland, with dead and dying trees was 300 400 hectares (742,300 acres) in 1978 (Table 1) compared to 197 000 hectares (486,000 acres) in 1977. The total merchantable volume of softwood trees in stands containing dead and dying trees and classified as A, B and C was 22 399 000 m^3 (9,294,000 cords) in 1978 compared to 15 354 000 m^3 (6,371,000 cords) in 1977.

In 1978 the percentage of dead and dying trees in stands classified as A, B and C was 29% and 22% respectively. The size of the merchantable stands classified as A, B and C and the volume of timber in them are presented by forest management units and by ownership in Appendix VI. Stands in class A contained a total volume of 4 319 400 m^3 (1,792,000 cords) of which an average of 68% (range 60 to 92%) was dead (2 939 100 m^3), an additional 13% (567 000 m^3) was forecast to die. In stands classed B containing a total volume of 10 078 100 m^3 (4,181,800 cords), 28% (2 785 400 m^3) was dead and 26% (2 609 700 m^3) dying. Stands in class C contained a total volume of 8 001 000 m^3 (3,319,900 cords) of which 10% was dead and 21% was forecast to die (Table 1, Figure 1). The net area of stands classified as "D - severely damaged, likely to recover" was about 639 000 hectares (1,580,000 acres).

Table 1. Area and total volume of mature stands where tree mortality caused by spruce budworm was evident in 1978.

	A (Dead)*	B (Moribund)*	C (Very severe)*	Total
Total area, ha	66 386	126.664	107 336	300 386
Dead vol. m^3	2 939 096	2 785 432	822 499	6 547 027
Dying vol. m^3	566 972	2 609 661	1 664 035	4 840 668
Total vol. m^3	4 319 396	10 078 126	8 000 998	22 398 521
Total area, ac.	164,045	312,994	265,234	742,273
Dead vol. cds.	1,219,542	1,155,781	341,286	2,716,609
Dying vol. cds.	235,258	1,082,847	690,471	2,008,576
Total vol. cds.	1,792,281	4,181,795	3,319,916	9,293,992

*A (Dead): 50% or more of total volume of stand dead.

B (Moribund, unlikely to recover): 20 to 49% of total volume of stand dead or more than 49% of total volume dying.

C (Very severely damaged, likely to recover): 5 to 19% of total volume dead or 5 to 49% of total volume dying.

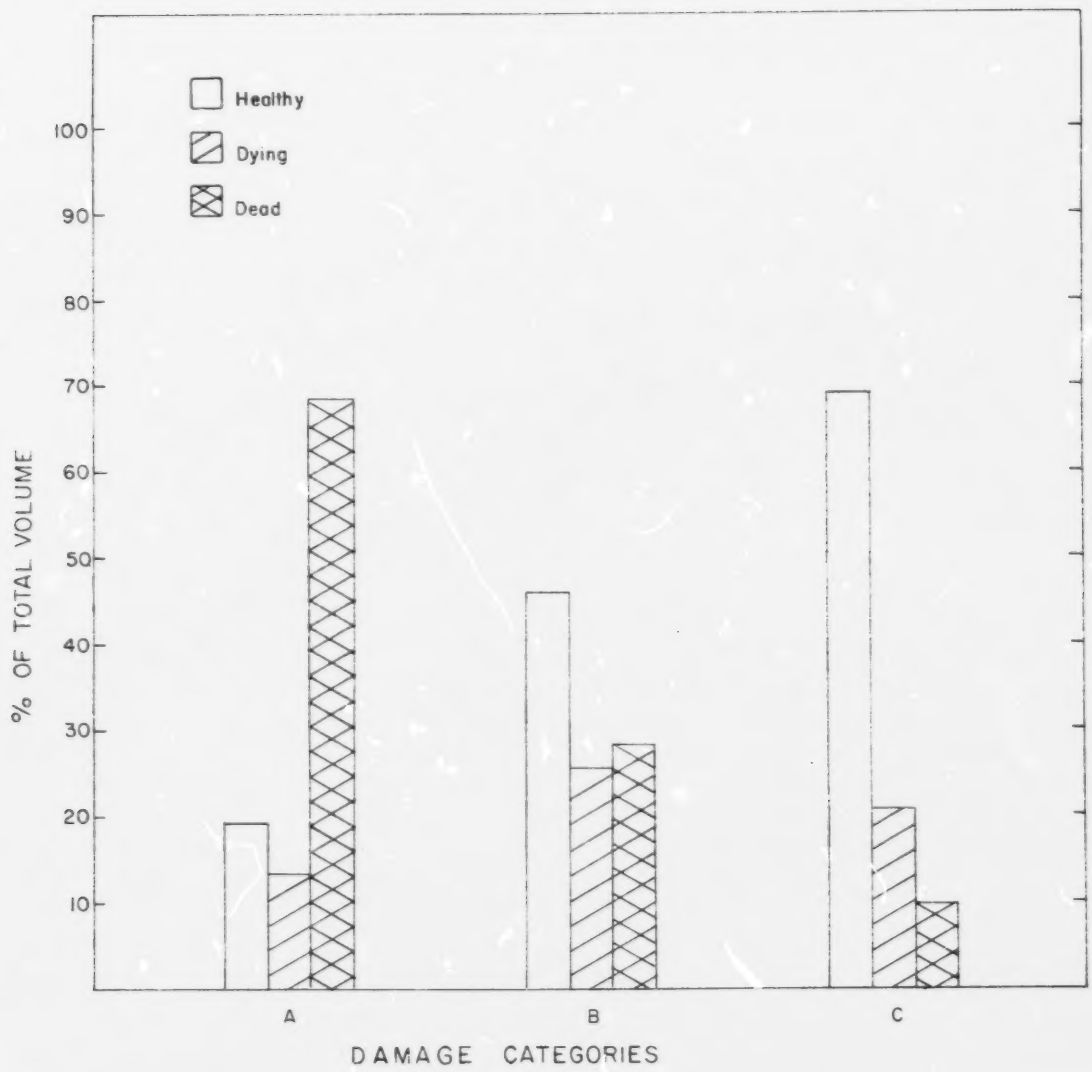


Figure 1. Average percent of dead, dying and healthy trees in spruce budworm damaged stands classified as A-Dead, B-Moribund and C-Very severely damaged.

The four categories of damage A, B, C and D were considered most suitable in 1978 (Appendix VII). However, the actual percentages of trees with various damagewere recorded andclass limits of these categories may be changed to satisfy changing conditions or requirements. For example, in Appendix VIII total volumes for categories A, B and C were combined to give dead and dying trees per ownership and forest management unit.

The effect of the spruce budworm to 1978 on the total softwood supply for insular Newfoundland is already quite serious, especially in western Newfoundland. Appendix IX relates tree mortality to total merchantable volume damaged or undamaged in each management unit. The dead and dying portion of the gross merchantable volume was very high, 25.6% and 17% in Bowaterlimits and in Crown land in management units 14 and 15 respectively. The percent balsam fir by volume was more than 75% in these units, and many of the stands had previous damage by other insects which made them more vulnerable to budworm kill. The other management units have a higher component of black spruce in the softwood volume and therefore balsam fir mortality in these units was not as severe.

Aerial damage assessments were also conducted in immature stands of balsam fir on the Island. The assessments were augmented by recordings of damage in permanent sample plots. The area of very severely damaged stands with tree mortality increased from 20 000 hectares (50,000 acres) to 32 000 hectares (78,000 acres) in 1978. However, the area of young stands in the moderate to severely damaged category without mortality decreased from 692 000 hectares (1,709,000 acres) in 1977 to about 365 000 hectares (879,000 acres) in 1978. This decrease was caused in part by rapid recovery of vigorous young stands where the spruce budworm population had collapsed as a result of natural causes and in part by the increase in the size of areas with mortality.

In Labrador the spruce budworm infestation has virtually collapsed. The scattered volume of dead and dying trees has not increased appreciably from 770 000 m^3 (320,000 cords) reported in 1977.

Progress of Tree Mortality

Mortality of balsam fir trees of merchantable size (dbh $\geq$ 9 cm) in Ontario and Quebec generally started after five years of severe defoliation (Blais 1958). However, in western Newfoundland, mortality started earlier in stands under stress from previous damage by other insects such as hemlock looper, balsam woolly aphid and the balsam fir sawfly or where severe backfeeding by the spruce budworm had occurred. The average percent mortality by year obtained from the 1977 and the 1978 damage assessments were used to estimate the tree mortality rates in Newfoundland (Figure 2). The volume of trees dead for 5 or more years totalled about 5% (range 3.5 to 54%) of the total merchantable volume in stands classified as dead on Bowater limits, about 6% (range 2.9 to 13%) on Price limits, about 9% (range 3.5 to 20%) on Crown Land and overall average of about 7% on all

ownerships combined. Tree mortality predicted for 1979 was based on the percent volume of dying trees from the 1978 damage assessment.

Blais (1958) reported that in Quebec it took two years for mortality of merchantable trees to increase from 25 to 75% of the total mortality that would eventually occur. Also, once cumulative defoliation had been sufficient to cause some trees of merchantable size to die, subsequent tree mortality was to some degree, independent of subsequent defoliation. Even if tree mortality may be slower in Newfoundland than in Quebec, it is expected that at least 50% of the volume of stands in category C will move into categories B or A by 1981 even without further defoliation. Mortality will continue to occur in severely damaged stands up to three years after the collapse of the spruce budworm outbreak.

When "dead" stands were classed by degree of accessibility about 60%, 64% and 92% were accessible by existing roads on Bowater, Price and on Crown lands respectively, or an average of 67% on all limits combined. An additional 7% may become accessible through road construction already planned. It was estimated that about 8% and 18% of the total volume of "dead" stands were in accessibility classes "3" (road construction required and major water bodies to be crossed) and "4" (more than 50% volume on steep slopes greater than 30%) respectively.

In 1978, 99% of the total volume of tree mortality was balsam fir, and this mortality occurred in stands which contained more than 75% balsam fir. The volume of merchantable-sized balsam fir on the island of Newfoundland was estimated at 1 375 000 m^3 (56,900,000 cords) (Anon. 1974) which comprised 49% of the total volume of all tree species. Therefore, the total volume of tree mortality to date was estimated as 5% of the total volume of balsam fir on the Island. The total volume of trees in dead, moribund and very severely damaged stands (Classes A, B and C) was about 16% of the total volume of balsam fir or 8% of the total merchantable volume of all timber on the Island.

Accuracy of the Damage Assessment Survey

In 1977 the location and size of dead and moribund stands determined from aerial survey were superimposed upon inventory maps and the acreage and total softwood volumes of the whole stand computed and collated. However, these volumes of dead or moribund timber presented did not imply that every tree in the stand was dead or moribund, but that from a "silvicultural" viewpoint the stand as a whole would be classed as such (Otvos and Moody 1977). Therefore, most volume figures of damage in 1977 represented estimates of total stand volumes and not the volume of only the affected trees.

In the 1978 damage assessment the areas of dead and moribund stands were delineated after a detailed aerial survey and percent stems dead or moribund was later checked by ground plots. With trained observers in the air,

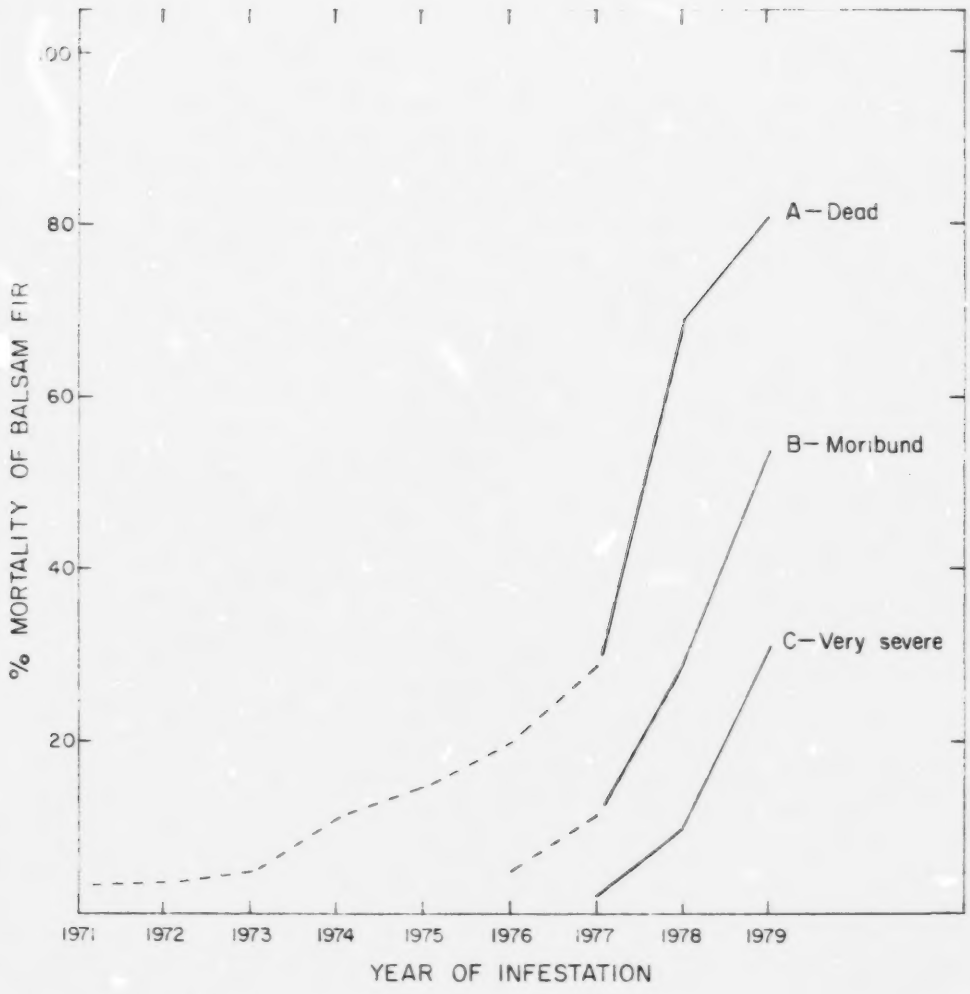


Figure 2. Mortality of balsam fir by year of occurrence and projected mortality for 1979 in stands classified as: A-Dead, B-Moribund and C-Very severely damaged. Pre 1977 mortality (---) was estimated from saprot penetration of dead trees during the 1977 special ground survey.

major damage categories can be delineated within about 0.5 km (¼ mile) or 1.6 mm (1/16 inch) on the small scale topographic maps. The results from the 1978 ground checks indicated that the percent volume of wood dead was only 85% of that calculated from the number of stems dead. Therefore mortality was occurring mainly in the smaller-than-average sized trees. Also, from ground plots the percent of dead stems in a stand was directly related (r = .93) to the percent dead volume in a stand so that if one is known the other can be inferred with good accuracy.

There was at times significant differences in percent stems dead or moribund between estimates made from aerial and ground surveys. The accuracy of the aerial survey was determined by calculating a mean percent error based on the estimated percent dead volume as determined by the ground plots. This statistic was calculated as follows:

$$\frac{a - g}{g} \times 100 = \% \text{ Error}$$

where a = % volume dead or moribund estimated (from % stems) from aerial survey

g = % volume dead or moribund from ground plots.

The error for damage class A, including both dead and dying trees, was -18%, that is, the estimate of the aerial survey was 18% lower than the estimate of the ground plots. The error in the B category for the combination of dead and dying trees was -10% (Table 2). The high error in the A category was probably caused by the requirement of dead cambium for classifying completely defoliated trees in the ground survey as dead.

Table 2. Summary of aerial observations of tree damage in Newfoundland in 1978 as compared with ground checks.

Damage category	Volume (1,000's m^3) Aerial survey Dead	Aerial survey Dying	Ground check Dead	Ground check Dying	Dead & dying[g]	$\frac{1 - g}{g} \times 100$ = % error
A - Dead	4,542[a]	-*	3,826	1,723	5,549	-18
B - Moribund	-*	1,061[a]	549	630	1,179[g]	-10

*In the aerial survey an area was classified as either dead or moribund.

CONCLUSIONS

The presently used aerial survey augmented with ground checks to assess spruce budworm damage in Newfoundland provides data on a Province-wide basis in sufficient detail for general planning purposes in a relatively short period of time without the dependence on more expensive remote sensing methods.

As a result of the present spruce budworm infestation, the balsam fir component in forest management units 4, 5, 6, 7, 9, 10, 12, 13, 14, and 15 has been severely damaged and stands contain a high percentage of dead and dying trees. Additional mortality of balsam fir will occur even without future spruce budworm feeding in areas totalling 300 400 hectares classified as A, B, and C. The areas classified as D - severely damaged with predicted high spruce budworm population for 1979 - could progress to the C or B categories if populations are not reduced by natural or applied control factors in 1979.

LITERATURE CITED

Anon. 1974. 1969 Inventory statistics of forests and forest lands on the island of Newfoundland. Government of Newfoundland, 71 pp.

Blais, J.R. 1958. The vulnerability of balsam fir to spruce budworm attack in northern Ontario with species reference to the physiological age of the tree. For. Chron. 34:405-422.

Hudak, J., G. Laflamme and J.P. Meades. 1978. Deterioration of balsam fir damaged by the eastern hemlock looper in Newfoundland. Envir. Canada, Can. For. Serv., Nfld. For. Res. Centre, St. John's, Nfld., Info. Rpt. N-X-157. 33 pp.

Otvos, Imre S. and B.H. Moody. 1978. The spruce budworm in Newfoundland: history, status and control. Envir. Canada, Can. For. Serv., Nfld. For. Res. Centre, St. John's, Nfld. Info. Rpt. N-X-150. 76 pp.

Appendix I. Map of the productive forest area of Newfoundland and Labrador.

Appendix II. Spruce budworm damage assessment map produced by two trained observers on an aerial survey in 1978.

Appendix III. Areas severely damaged by the spruce budworm and the location of ground plots (dots) within these areas in 1978.

Appendix IV. FIDS spruce budworm damage assessment data form and instructions

Sp.	D.B.H.	Hgt.	Dead	Living		Defol.		Recovery				Sap rot pen.	Remarks
				Dead top	Living top	Cur.	Prev.	G	F	P	Nil		

Appendix IV continued

For old defoliation the following categories are to be used:

Category	% defoliation	Damage
0 - Zero	0	No apparent damage except to current year's foliage
L - Light	1-25	Some defoliation evident on previous growth, particularly on previous year's growth. No bare top.
M - Moderate	26-75	Thin crown, short bare top, defoliation evident on at least two previous year's twigs.
S - Severe	76-100	Marked defoliation on two or more year's growth; crowns thin and grayish in appearance and frequently two or more feet of bare top.

Damage: Dead tops, record percentage of trees with dead tops.
Dead trees, record percentage of dead trees.

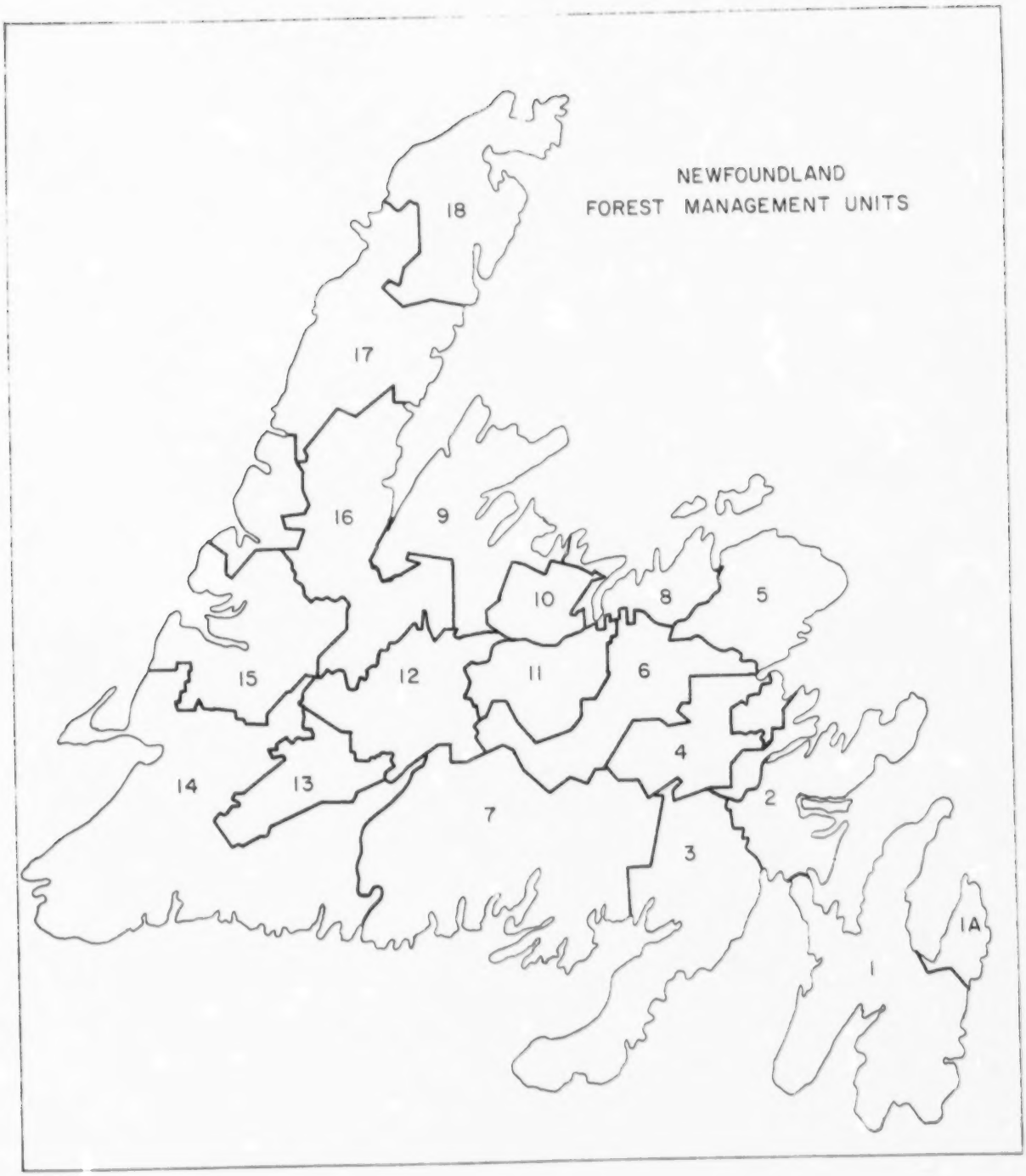
Tree vigor

G - Current foliage apparently normal or nearly normal. Trees evidently capable of rapid recovery.

F - Shoot production moderately affected, obviously less vigor but with evidence of ability to recover.

P - Current shoots present but sparse. Tree clearly demonstrating serious deterioration of growth capability.

N - Dying. No old foliage, few current or adventitious shoots only.



Appendix V. Map of the Newfoundland forest management units

Appendix VI. Spruce budworm damage assessment survey in merchantable stands in 1978. Volume based on 2.41 m^3/cord.

Management unit no.	Ownership	Area and volume affected											
		A (Dead)*				B (Moribund)*				C (Very severe damage)*			
		Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)	Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)	Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)
1	Crown	-	-	-	-	1 947	67 367	1 518	52 374	710	40 389	-	13 429
2	Crown	-	-	-	-	74	7 531	-	4 519	926	40 061	-	[illegible]
4	Price	552	36 516	29 214	-	4 387	262 892	46 205	128 945	2 061	189 359	-	[illegible]
5	Crown	-	-	-	-	-	-	-	-	832	83 675	-	[illegible]
	Bowaters	-	-	-	-	226	22 902	-	13 739	338	34 251	1 013	[illegible]
	Price	422	42 691	25 613	-	156	14 807	-	8 883	2 072	143 084	13 879	[illegible]
6	Crown	143	8 165	5 717	-	-	-	-	-	-	-	-	-
	Bowaters	-	-	-	-	8 009	791 212	202 734	3 817	2 012	191 462	24 524	[illegible]
	Price	-	-	-	-	-	-	-	-	296	29 896	-	[illegible]
7	Crown	1 368	63 525	58 690	-	6 912	353 436	75 189	180 092	9 331	572 673	53 200	[illegible]
8	Crown	-	-	-	-	442	48 200	-	28 920	2 027	126 802	3 977	[illegible]
	Bowaters	-	-	-	-	-	-	-	-	816	23 273	-	[illegible]
9	Crown	3 485	242 916	175 499	36 360	2 000	213 280	47 190	97 552	2 753	182 063	583	[illegible]
	Bowaters	3 629	296 256	216 924	48 116	10 109	905 244	256 930	312 970	6 618	572 879	2 463	[illegible]
10	Crown	-	-	-	-	-	-	-	-	1 027	31 316	5 825	[illegible]
	Price	3 950	133 861	98 248	9 315	3 296	186 539	67 121	56 628	6 988	263 611	24 078	[illegible]
11	Price	-	-	-	-	2 240	86 955	-	52 174	159	12 725	-	[illegible]
12	Crown	68	5 900	5 131	-	-	-	-	-	-	-	-	-
	Price	6 770	461 927	363 308	27 358	1 658	122 517	11 327	53 825	1 149	76 840	831	[illegible]
13	Price	150	15 694	10 985	-	1 571	125 161	46 323	4 593	1 777	135 828	12 026	[illegible]
14	Crown	16 571	955 495	617 606	161 058	12 297	1 069 457	342 316	229 687	14 501	1 213 888	213 215	[illegible]
	Bowaters	5 759	461 363	290 875	43 802	21 433	1 792 707	703 734	205 727	12 791	1 066 420	153 805	[illegible]
15	Crown	-	-	-	-	4 696	400 940	104 242	68 639	1 505	107 582	-	[illegible]
	Bowaters	10 290	796 693	537 963	98 198	13 487	1 184 067	362 772	259 145	15 187	1 207 983	123 619	[illegible]
16	Crown	-	-	-	-	9 965	899 123	95 788	440 926	6 429	484 364	44 180	[illegible]
	Bowaters	4 128	318 448	209 945	41 744	7 089	529 506	138 864	175 046	4 687	336 146	44 510	103 999

Cont'd ...

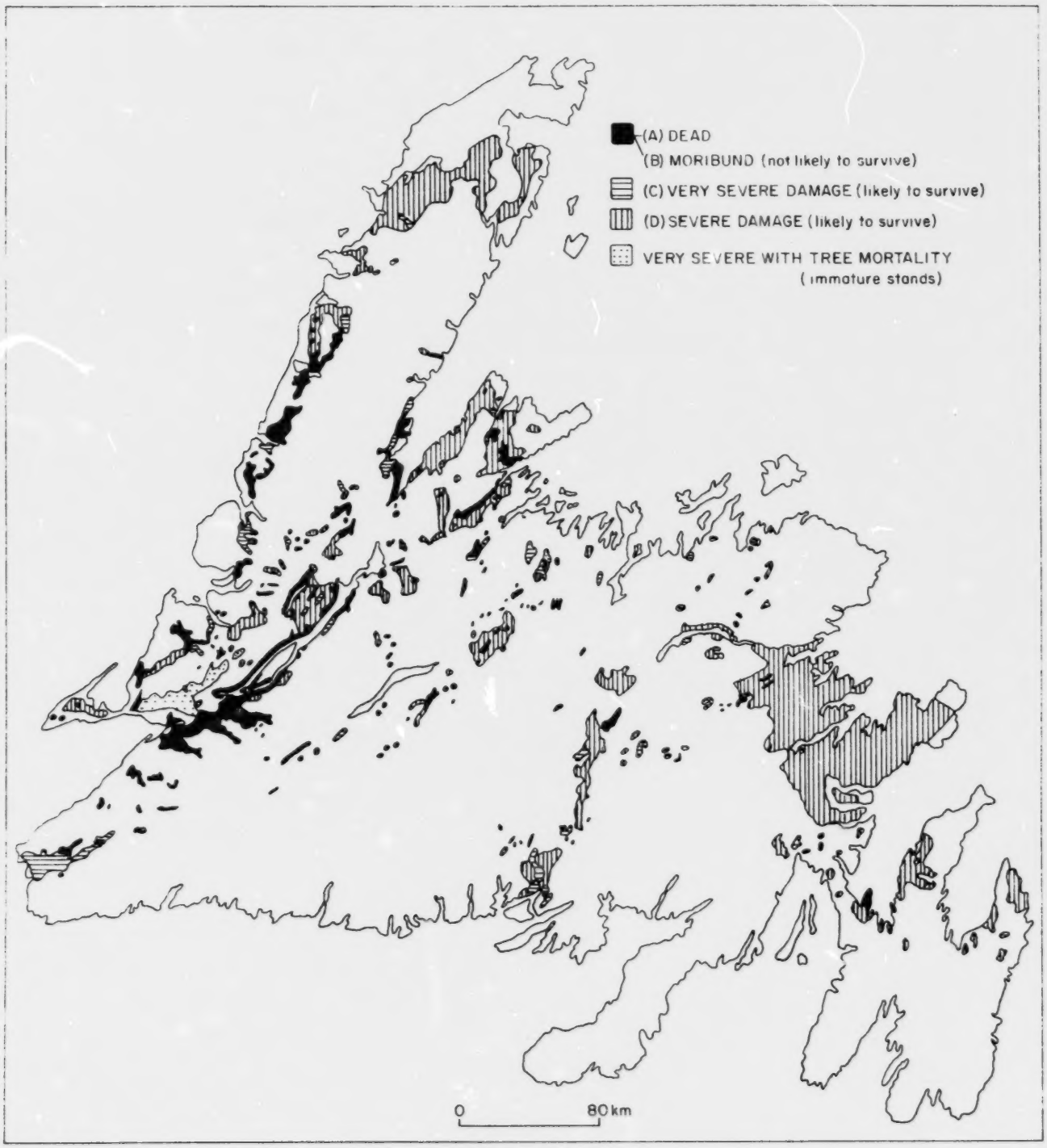
Appendix VI. - Concluded

Management unit no.	Ownership	Area and volume affected											
		A (Dead)*				B (Moribund)*				C (Very severe damage)*			
		Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)	Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)	Total area (ha)	Total vol. (m^3)	Dead vol. (m^3)	Dying vol. (m^3)
17	Crown	3 076	85 555	49 600	16 593	1 659	147 492	5 350	95 588	506	50 610	-	8 315
	Bowaters	5 832	382 036	232 659	84 430	275	18 027	6 309	2 704	3 628	282 170	14 607	57 057
	GMNP	193	12 356	11 120	-	12 736	828 763	271 518	133 167	4 130	319 785	51 967	30 744
14	Private	-	-	-	-	-	-	-	-	2 181	181 858	34 188	36 372
All	Crown	24 711	1 361 556	912 242	214 010	39 991	3 206 826	671 594	1 198 298	40 447	2 933 425	320 968	704 421
	Bowaters	29 638	2 254 796	1 488 365	316 288	60 629	5 243 666	1 671 345	973 148	46 077	3 714 586	364 560	728 842
	Price	11 844	690 689	527 368	36 673	13 307	798 872	170 975	305 048	14 501	851 342	50 815	163 656
	GMNP	193	12 356	11 120	-	12 736	828 763	271 518	133 167	4 130	319 785	51 967	30 744
	Private	-	-	-	-	-	-	-	-	2 181	181 859	34 188	36 372
Total Island**		66 386	4 319 397	2 939 096	566 972	126 664	10 078 126	2 785 432	2 609 661	107 336	8 000 998	822 499	1 664 035
Total Island (Area in acres, vol.in cords)		164 045	1 792 281	1 219 542	235 258	312 994	4 181 795	1 155 781	1 082 847	265 234	3 319 916	341 286	690 471

*A (Dead): 50% or more of total volume of stand dead.
B (Moribund, unlikely to recover): 20% to 49% of total volume of stand dead or more than 49% of total volume dying.
C (Very severe damage, likely to recover): 5% to 19% of total volume dead or 5% to 49% of total volume dying.

GMNP, Gros Morne National Park

** These figures have been converted directly from English to metric measurements, therefore columns do not total exactly.



Appendix VII. Map of the different classes of spruce budworm damage in 1978 in Newfoundland.

Appendix VIII. Summary of areas and volumes of merchantable stands with tree mortality caused by the spruce budworm by management unit and ownership in 1978.

Management Unit	Ownership	Total Areas (Ha) A, B, C	Total Vol. (M^3) A, B, C	Total Vol. Dead & Dying A, B, C (M^3)	% Vol. Dead	% Vol. Dying
1	Crown	2657	107756	67321	1.4	61.1
2	Crown	1000	47593	9927	-	20.8
4	Price	7000	488767	251093	15.4	35.9
5	Crown	832	83675	30593	-	36.6
	Bow.	564	57153	21078	1.8	35.1
	Price	2649	200582	69839	19.7	15.1
6	Crown	143	8165	5731	70.0	-
	Bow.	10021	982675	262866	23.1	3.6
	Price	296	29896	11958	-	40.0
7	Crown	17612	989623	514981	18.9	33.0
8	Crown	2469	175002	43047	2.3	22.3
	Bow.	816	23273	6982	-	29.9
9	Crown	8237	638260	405470	34.9	28.5
	Bow.	20356	1774379	990549	26.8	28.9
10	Crown	1027	31316	14655	18.6	28.2
	Price	14234	584010	317151	32.4	21.9
11	Price	2398	99680	54719	-	54.9
12	Crown	68	5900	5131	86.9	-
	Price	9578	661285	469620	56.8	14.2
14	Crown	43369	3238840	1828563	36.2	20.2
	Bow.	39983	3320491	1647963	34.6	15.0
15	Crown	6202	508522	191744	20.5	17.2
	Bow.	38964	3188743	1501240	32.1	14.9
16	Crown	16293	1383487	728960	10.1	42.6
	Bow.	15905	1184100	714107	33.2	27.1
17	Crown	5241	283657	175446	19.4	42.5
	Bow.	9735	682232	397766	37.2	21.1
	GMNP	17059	1160904	498516	28.8	14.1
14	Private	2181	181858	70560	18.8	20.0
13	Price	3498	276806	80154	25.1	3.9
ALL	ALL	300387	22398509	11387730	29	22

Appendix IA. Summary of Spruce Budworm Effect to 1978 on Wood Supply for Insular Newfoundland by Forest Management Unit and Ownership and Damage Classes A and B.

Management unit	Ownership	Productive area[1] (000's ha)	Softwood Volume[2] Gross merch. volume[3] (000's m^3)	Softwood Volume[2] Net merch. volume[3] (000's m^3)	Area of dead & moribund stands[4] (ha)	Vol. of dead & moribund stands[4] (000's m^3)	% of total area dead & moribund	% of gross merch. vol. dead & moribund
1	Crown	125	3,970	3,679	1,947	67	1.6	1.7
2	Crown	169	6,934	5,963	74	8	0.0	0.1
3	Crown	53	2,110	1,673	-	-	-	-
4	Price	97	4,535	4,257	4,939	299	5.1	6.6
5	Crown	107	3,771	3,539	-	-	-	-
	Price	23	1,009	947	578	57	2.5	5.7
	Bowater	94	2,658	2,492	226	23	0.2	0.9
6	Price	15	470	431	-	-	-	-
	Bowater	162	10,727	9,914	8,009	791	4.9	7.4
7	Crown	62	2,956	2,256	8,280	417	13.4	14.1
	Bowater	86	4,804	3,811	-	-	-	-
8	Crown	138	6,762	6,148	442	48	0.3	0.7
	Price	5	274	257	-	-	-	-
	Bowater	22	1,331	1,248	-	-	-	-
9	Crown	73	4,394	3,646	5,485	456	7.5	10.4
	Price	49	3,306	3,101	-	-	-	-
	Bowater	171	10,829	10,060	13,738	1,202	8.0	11.1
10	Price	99	5,634	5,388	7,246	320	7.3	5.7
11	Price	162	7,360	6,773	2,240	87	1.4	1.2
12	Price	184	9,846	8,630	8,428	584	4.6	5.9
13	Price	73	4,570	4,020	1,721	141	2.4	3.1
14	Crown	177	12,093	9,645	28,868	2,025	16.3	16.7
	Bowater	136	8,809	7,084	27,192	2,254	19.9	25.6
15	Crown	35	2,361	1,675	4,696	401	13.4	17.0
	Bowater	268	17,702	13,022	23,777	1,981	8.8	11.2
16	Crown	59	5,054	4,120	9,965	899	16.8	17.8
	Bowater	154	10,618	8,921	11,217	848	7.3	8.0
17	Crown	53	3,628	2,169	4,735	233	9.0	6.4
	Price	37	3,745	2,608	-	-	-	-
	Bowater	77	6,936	5,584	6,107	400	7.9	5.8
18	Crown	64	5,119	3,044	-	-	-	-
	Price	8	701	542	-	-	-	-

Appendix IX - concluded

Management unit	Ownership	Productive area[1] (000's ha)	Softwood Volume[2] Gross merch. volume (000's m^3)	Softwood Volume[2] Net merch. volume[3] (000's m^3)	Area of dead & moribund stands[4] (ha)	Vol. of dead & moribund stands[4] (000's m^3)	% of total area dead & moribund	% of gross merch. vol. dead & moribund
18	Bowater	73	6,736	5,436	-	-	-	-
ALL	Crown	1,114	59,152	47,557	64,492	4,554	5.8	7.7
ALL	Price	754	41,451	36,955	25,152	1,490	3.3	3.6
ALL	Bowater	1,245	81,150	67,574	90,266	7,498	7.2	9.2
	Total:	3,113	181,753	152,086	179,910	13,542	5.8	7.4

[1] Lands capable of producing at least 10 cunits per acre, Newfoundland Forest Service.

[2] Existing volumes of balsam fir and spruce in stands containing $\geq$ 5 cunits per acre, Newfoundland Forest Service.

[3] Net merchantable volume excludes cull and timber on steep slopes (> 30%).

[4] From Appendix VI Columns A & B.